paper and not to physical limitations of the invention unless specifically noted. The drawings are not to scale, and some features of embodiments shown and discussed are simplified or amplified for illustrating principles and features, as well as anticipated and unanticipated advantages of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0018] The present patent application is related to U.S. patent application Ser. No. 13/045,493 which shares at least one common inventor with the present application and has a common assignee. Said related application is hereby incorporated herein for all purposes by this reference.

[0019] It has been determined that data may be transferred efficiently among coupled coils. Generally, using inductive coupling, a primary coil is positioned in proximity to a secondary coil. The primary and secondary coils are properly oriented and positioned so that they may be electromagnetically coupled in order to facilitate a transfer of energy between them. Generally, one primary coil is used with one secondary coil, and secondary side systems are designed to resonate at a particular frequency. This allows for more efficient transfer of energy at that particular frequency. The inventors have reduced to practice a novel and useful improved coupled inductor data transmission system using multiple inductor coils, on the order of 10's to 100's of nano-Henries, switched at high frequencies, on the order of 10's to 100's of MHz. The multiple coils of the system can be dynamically coupled based on operational considerations.

[0020] The systems of the invention can be utilized for high bandwidth wireless data transmission as well as for wireless power transmission. Preferably, the primary and secondary coils are not permanently physically connected with one another. Each of the coils is preferably connected with additional circuitry designed for particular functionality. For example, the primary coil may be associated with data signal transmitting circuitry, and the secondary coil may be associated with corresponding data receiving circuitry. The respective coils typically reside in electronic apparatus or systems of various kinds. For example, the primary coil may reside within a battery charger or power inverter apparatus, and the secondary coil may reside in communication, computer, battery, imaging, or other portable apparatus, to cite a few examples. The respective coils are positioned within their respective apparatus such that, in operation, they may be placed in physical proximity for inductive coupling such that the coils are in communication with one another for the exchange data, and in some cases power. The system drives the primary coil on one side to transmit, and receives at the secondary coil on the other side. Such systems can be utilized for high bandwidth communication as well as power transfer across the inductive coupling between the primary and secondary coils. Transmitter, receiver, or transceiver apparatus may be used as desired for the particular implementation, using available communications equipment in combination with the multiple coil data transmission system.

[0021] In the coupled inductor system according to the invention, a signal from a primary side driver is transmitted through a primary side coil to a secondary coil. If a data receiving circuit or load is connected to the secondary coil, the electric current from the secondary coil can be used to transmit data and/or to power the load. An example of a preferred embodiment of a coupled inductor system for wireless data transfer according to the invention is shown in FIG. **1**. The system **100** includes a primary side **102** for providing one or more signals to a secondary side **104** receiver. The primary side **102** has multiple primary coils **106***a*, **106***b*, **106***c*, and driver circuitry **108**. By using several primary coils **106** instead of a single coil, the size of each coil can be kept small and a large total area for inductive coupling can still be provided. The secondary side **104** has one, and preferably multiple coils **110***a*, **110***b*, **110***c*, for receiving signals from the primary side **102**. In a system **100** with multiple primary coils **106**, the primary coils preferably can be driven all simultaneously, one at a time, or in selected combinations. One or both sides (primary and secondary) of systems constructed in accordance with the invention can be built with multiple selectable coils.

[0022] In operation, with multiple coils arrayed in the system **100**, as in this example using multiple primary side coils **106** and multiple secondary side coils **110**, it is possible, using the primary side circuitry **108**, to detect the presence and location of a secondary side coil **110** by using appropriate sensors arranged to sense changes in the current on the primary side coils **106**. Proximity sensing preferably detects activity on a coil **106** by technology and techniques known in the arts. Activity on the coil **106** can be detected by rectifying the signal on the coil terminals and detecting the input power, for example. This detected power can be compared to a known threshold to determine whether the coil **106** is being driven by another coupled coil **110**. Alternatively, the system **100** can be configured to sense the presence of a signal on the coil **106**. Activity on the coil(s) **106** may be detected with or without first rectifying the signal. For example, coil activity can be sensed either from one terminal to ground or between the terminals. Upon detection of the position of a secondary side **104** receiving coil, e.g. **110**(*a*), in proximity suitable for inductive coupling, then the appropriate transmitting coil or coils, e.g., **106**(*a*), closest to and/or best aligned with the detected receiving coil **110**(*a*) can be driven. In the event multiple transmitting coils can favorably be driven, each may be driven with a different drive strength selected to increase the overall the signal integrity in the system **100**. It is within the scope of the invention to use the systems described and shown for transmitting power in addition to, or in some instances, instead of data.

[0023] An example of a preferred embodiment of a coupled inductor system for wireless data transfer according to the invention is shown in FIG. **2**. The system **200** includes a primary side **202** for providing one or more signals to a secondary side **204** receiver. The primary side **202** has driver circuitry **208** for driving one or more primary coil **206**. The primary coil(s) **206** have one or more selectable tap points **210** activated by a switch **212** such that the effective size, and thus the frequency and resonance quality, or Q, of the primary coil(s) **206** can be changed dynamically. By manipulating the switch(es), e.g., **212** and changing the tap point **210**, the radius of the coil **206** is changed based on a sense of the data integrity, coupling coefficient, or other system parameter detected by the primary side driver circuitry **208**. This system **200** may be implemented using multiple coils **206** having one or more alternative tap points **210** such that various combinations may be selected dynamically according to operational requirements.

[0024] An additional example of another preferred embodiment of a multiple coil coupled inductor system for wireless power transfer according to the invention is shown in FIG. **3**. The system **300** includes a primary side **302** for providing one